GAR WOOD INDUSTRIES INC. (A)

Failures at Welded Joints in a Hopper Trailer

In the middle part of 1953 the Richmond Division of Gar Wood Industries Inc. began building a line of frameless hopper type truck trailers. Failures were experienced in service on early models at welds in the ends of the body structures. E.G.Hirtle, Gar Wood's Chief Engineer at Richmond, California, was responsible for design changes to eliminate these failures.

 Prepared in the Stanford Engineering Case Program by John Alic under the direction of Prof. H.O. Fuchs with support from the National Science Foundation. Helpful cooperation of Gar Wood Industries Inc. is greatly appreciated.

Gar Wood's truss framed trailer proved generally unsatisfactory; durability was poor -- the bodies did not hold up in service -- and after the design had been in production for about a year, the decision was made to abandon it and design a new trailer. Gar Wood's management considered the truss framed trailer excessively expensive to build and it was also quite costly to fix trailers that came back to Richmond for repair.

Gar Wood's trailers have a six month warranty -- the standard warranty in the industry -- but Mr. Hirtle explained that they would often repair trailers that were a year or even two years old because such service led to satisfied customers and repeat sales. In particular, when one of their products showed a chronic problem, Mr. Hirtle said he felt that it was good customer relations to provide repairs beyond the terms of the warranty.

When Gar Wood's management decided that it was not economically feasible to continue building the truss framed trailer, the Richmond engineering staff began an all-new design. At this time, in 1953, the engineering staff numbered nine, six of whom were graduate engineers, plus two girls. The staff had shrunk to four by 1965 partly because of a cutback in the number of detailed engineering records kept (such as engineering change notices) and partly because Richmond is not presently engaged in any major design/development projects. In 1953-54 a land leveling scraper and a land-leveling bulldozer were under development in addition to the hopper trailers.

During this period Gar Wood's Northwest Distributor, in Seattle, had been requesting a body to compete with those offered by a local fuel tank truck manufacturer, who was taking oval-section tank bodies and cutting holes in the top and bottom, for loading doors and hoppers, respectively. This closed hopper body was set on a channel-section frame and used for hauling cement.

After seeing photographs of the tank trucks converted to cement trucks, Glenn Hicks, the project engineer on the new trailer, conceived a frameless hopper body design in which a stressed body skin of basically oval cross-section (for a closed body) would be augmented by longitudinal formed sheet metal angles welded to each of the lower body sides where the rails of a separate frame would normally go. The addition of this angle to the body skin gave a stiff triangular section "box" running along each side of the body between the front and rear wheels. This reinforcement was sufficient to allow the hopper body to function as the sole load bearing structure of the trailer, rather than merely as a container. The result was a considerable, and important, weight saving over a trailer with a separate body and frame, as well as simpler and cheaper fabrication. This is the design as shown in Exhibit 1; all models are generally similar -- length and height of the hopper are the only variables of importance.

The structures at each end of the hopper, hereafter called body ends, consist of channel sections of varying height (the distance between the two flanges of the channel increases as the hopper wall is approached) with the open sides facing inwards. These channels are called compression members. They tie into the triangular section "boxes" at each end of the hopper. Crosswise and longitudinal beams for the attachment of the springs and suspension links are located beneath the compression members. There is a crossmember between the bottom ends of the two compression members at both the front and rear of the bodies. The body ends are essentially the same front and rear and are also the same on all models.

Gar Wood makes 50 to 250 hopper trailers a year, usually in batches of 5 to 20. Most are sold to firms with headquarters in California; the trailers then see use throughout the Western States. The bodies are formed by welding together pieces of low alloy, high strength steel (such as U.S.Steel's "Cor-Ten" brand), the hoppers themselves being 12 gage (.105). The parts which make up a body are sheared out of hot rolled sheet. Steel templates are used when laying out the outlines of the pieces. Forming operations are performed on press brakes. Curves are cut with a nibbler. The cutting edges of this tool resemble two opposed chisels, one of which is power-driven, usually pneumatically, so that the device chews its way through the steel. Once cut and shaped, the pieces are clamped in fixtures and welded up by hand. A photograph of Gar Wood's shop showing early model trailers being fabricated appears in Exhibit 3. Three fixtures are used in the successive assembly operations. Welds are checked visually in the shop. Currently (1965), a train of 17 foot or 20 foot long trailers (2 trailers) sells for about $9000.

The original 1953 design of the body ends may be seen in the picture of the model 400-C-17 trailer at the top of Exhibit 1 and in the drawings of Exhibit 4 and Exhibit 6. Weld failures occurred at each end of the compression member. Failure areas are indicated in the sketches of Exhibit 5. The two main problems occurred at the welds joining the crossmembers at the front and rear of the bodies to the lower ends of the compression members and at the joint between the upper ends of the compression members and the hopper walls. The plate on which the undercarriage, or, in the case of a semi-trailer, the kingpin, is mounted is welded to the front crossmember; the rear crossmember is one of the attaching points for the spring suspension. At both ends of the compression member cracks originated in one or another of the welds and propagated along the weld or directly into the parent metal.

Mr. Hirtle said that it is often difficult to determine when a "problem" exists with failures of this kind. A chronic failure requires a redesign to eliminate it. But there are many variables to be considered and many possible non-problem failures. In the first place, Mr. Hirtle stated that the low alloy steels used in truck bodies tend to be "spotty" -- they may have non-uniform properties, and fatigue cracks may originate at a weak area in the parent metal or at a weak point where the weld metal and parent metal meet. It is thus unwise to conclude immediately that the design is faulty when a few cracks are discovered.

Most observed service failures were fatigue failures. But in general, the service conditions were unknown or shrouded in uncertainty. Besides that, many failures go unreported; the operators merely weld up cracks on the job. Trailers may be in use 1, 2, or 3 shifts per day. Loads vary depending on what is hauled, the terrain covered (many hopper trailers are used off the road at construction sites),and the general severity of use. Any trailer will break if abused sufficiently. Mr. Hirtle said that the best way to get an idea of service conditions is to go out in the field and watch the trailers in operation, perhaps even riding them.

Although the many different models in the Gar Wood line are basically similar, the difference in structure between the open and closed models may be significant in terms of the loads transmitted to the body ends. The covered top on the closed trailers would seem to give these models considerably more rigidity than the open models possess. There would thus be less tendency for the welds in the closed models to be twisted apart by the working of the bodies. Indeed, the first frameless trailers Gar Wood built in 1953 were closed and these did not show an appreciable problem at the welds where the compression members joined the hopper wall; this did not show up until the first open models were built. Both types, however, did exhibit failures in the crossmember to compression member welds.

A further difficulty over the several years of the trailer's development was that some of a group of identical trailers under similar operating conditions might fail almost immediately after going into service, and some seemed never to fail. Some of Gar Wood's original 1953 model trailers are still in use and a few have never needed any rewelding or reinforcement. Part of this variability may have been the result of unknown and undoubtedly varying residual stresses left in the bodies after assembly. Not only do the welding operations leave residual stresses, but since the bodies can never be expected to fit together exactly when assembled, they must often be forced into alignment by various means (hydraulic jacks are sometimes used) before welding.

All these factors,together with the low production rate combine to make it difficult to decide when enough failures have occurred for a problem to be considered to exist. When the design was revised to fix a problem, a period of several months, or perhaps even a year usually passed before the success of the redesign could be evaluated.

Although failures did occur in the two areas of the body ends, as shown, often enough for them to be considered problems, Mr. Hirtle stated that such failures are typical of new products in the truck equipment field where light weight is of great importance. The chronic failures in the previous truss type hopper trailer had been both more numerous and more severe. Mr. Hirtle explained that because of the emphasis on light weight it was best to design a new truck body as an absolute minimum structure and then to add reinforcements and perhaps additional load bearing members during the development period of the body if these were needed for added strength and durability.

When a customer brings Gar Wood trailers to Richmond for repair of failures at the specific points under discussion here or for other repairs, the usual procedure, whether the trailer is under warranty or not, is to weld up the crack and in most cases to add gussets or re-inforcing plates in an attempt to prevent recurrence of the failure. If design changes have been made since the manufacture of the particular trailer, these changes may be incoporated if the customer so requests.

Design Changes of the Joint Between the Compression Member and the Hopper

In the following account of design changes, only those major changes which had the status of re-engineering and were incorporated in a series of trailers, as opposed to repairs and trial fixes, are included. All parts are made of low alloy steel unless otherwise noted.

The original design of the joint between the compression member and the hopper wall as laid out in August, 1953, and shown in Exhibit 4, did not incorporate a separate bracket or gusset at the inside corner of the joint. The top of the compression member was all one piece as shown in the detail drawing of Exhibit 6. Although redrawn in October, 1953, no functional changes had yet been made to this piece. The one inch flange on the inside of the member was bent down and mated to a 16-1/8" x 1" x 14 gage (.075) strip which was curved to a 10-3/4" radius and welded into the member, continuing the flange around the curve to the hopper where the entire end of the compression member was butt welded to the wall.

This curved strip persisted in pulling away from both the flange and the compression member and in August, 1953, the joint was redesigned as shown in Exhibit 7. A crosswise channel section beam was added running across the outside of the hopper wall. This served to stiffen the wall and give a better weld where the compression members joined it. It also tied the two compression members in each body end together more positively, adding to the rigidity of the entire structure. The compression members butting against this channel were also modified. The curve on the top inside of the member was eliminated and the one inch bent-down flange on the inside run straight back to the channel section. Then a 14 gage (.075) curved gusset plate was welded into the corner and its edge re-inforced with another one inch deep flange. The curved flange strip was now made of 12 gage (.105) rather than 16 gage (.060) stock, and was lengthened considerably over the corresponding part in the 1953 design. The ends were extended to allow fillet welds to be used instead of butt welds and pointed to spread the stresses over a greater area of the parent metal.

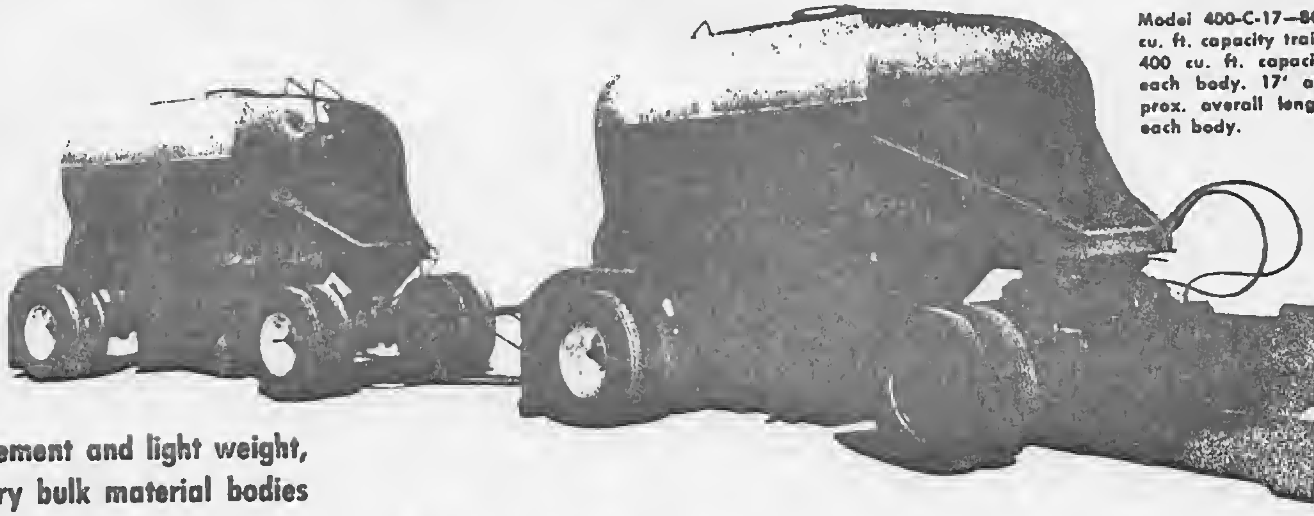
The revised design was not satisfactory. Although the redesigned trailers generally lasted longer in service before cracks appeared, about the same percentage eventually failed. The curved flange again broke loose along the welds holding it to the gusset, channel section, and compression member. Cracks also appared at the inside corner where the compression member met the channel section and the gusset was welded in.

An attempt was made in the succeeding months to improve the life of the joints by double-welding -- that is, welding each seam from both sides. Not only does this tend to increase the static strength of the structure, but by eliminating the crack left on the side of the joint opposite the weld -- be it a fillet weld on overlapping pieces or a butt weld without complete penetration -- the fatigue life of the joint will be improved. Mr. Hirtle said that this is often the obvious thing to try in order to improve the fatigue life of a part, but that double welding in many places can be quite expensive if one side of the seam is not easily accessible Often, he said, the decision on whether to try such a fix is a matter of economics. Double-welding on the corner brackets showed no appreciable improvements in durability and the practice was discontinued after several months.

Near the end of 1955, Mr. Hirtle decided upon a major change in the design philosophy concerning the joint between the compression member and the hopper wall. The original curved upper portion of the compression member was there to brace this member and keep it from deflecting appreciably under load. The structure was intended to be rigid. The redesigns had as their goal increased strength and greater rigidity. Mr. Hirtle now decided to <u>allow</u> the joint to flex, to discontinue attempts to make it rigid. The curved gusset and flange were removed entirely. The resulting corner was then left as an acute angle formed by the crosswise channel section and the compression member. A strap was then welded into the corner as shown in the sketch of Exhibit 10. The strap was 1-1/2" x 16" x 1/4" mild steel, pointed at the ends to give greater weld length and spread the stresses.

Unfortunately, with this design cracks developed right at the corner itself, behind the strap at the apex of the angle formed by the crosswise channel section and the compression member. Usually the crack would then move back into either the hopper wall or the compression member -- or both.

Exhibit 1: Page from 1953 Gar Wood Catalog Showing the Original Frameless Hopper Trailer Design.

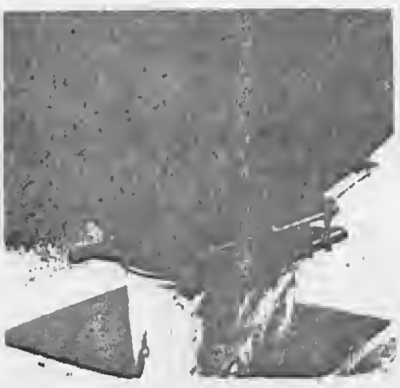


Model 400-C-17—800 cu. ft. capacity train. 400 cu. ft. capacity each body. 17' approx. overall length each body.

Cement and light weight, dry bulk material bodies

All-Weather Protection —

water-proof bodies, filling hatches and dumping valves



Water-tight dumping valve with cover plate, controlled by simple cam levers, gives complete load protection. Removable dumping boot shown attached. Valve operated entirely from side of trailer.

All-welded construction provides water-proof protection — eliminates water damage, customer rejections. No rivets to work loose and admit water. All internal body surfaces smooth and free from rivet heads or other projections for rapid, complete dumping.

Filling hatches fitted with vented, self-locking aluminum covers — allow free "breathing" during hauling and dumping — prevent water entering load during rainy weather. Vents readily accessible and easily cleaned.

Outstanding, new Gar Wood water-tight dumping valve gives complete load protection. Water-tight cover plate positively seals valve — eliminates clogged dumping gates, lumpy cement, caused by rainy weather, wet roads. Gates of time-proven butterfly construction assure easy dumping.

Dumping operation simple, safe, convenient. Operator not required to crawl under trailer. Water-tight cover plate readily removed for dumping by twisting a pair of simple cam levers, operated from side of trailer. Dumping gate also controlled from side of trailer.

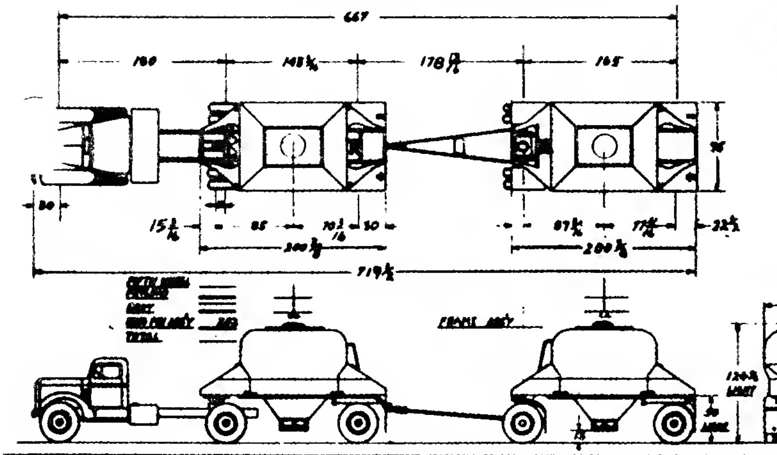
Removable dumping boot featured. Boot ring and water-tight cover plate designed so boot can not be left in place during loading and hauling — prevents wet or damaged boot. Boot carried in enclosed compartment behind hopper.

The GAR WOOD water-tight dumping valve protects against rainy weather, wet roads

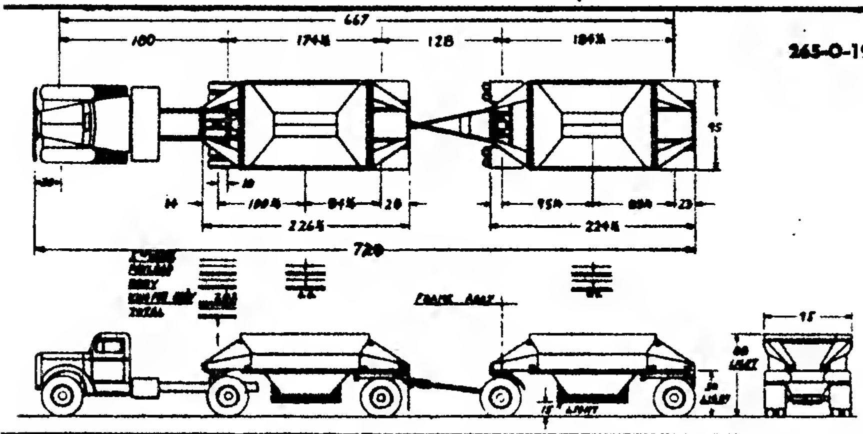
Model 660-C-35—660 cu. ft. capacity semi-trailer. 35' approx. overall length.

Dimensional Drawings

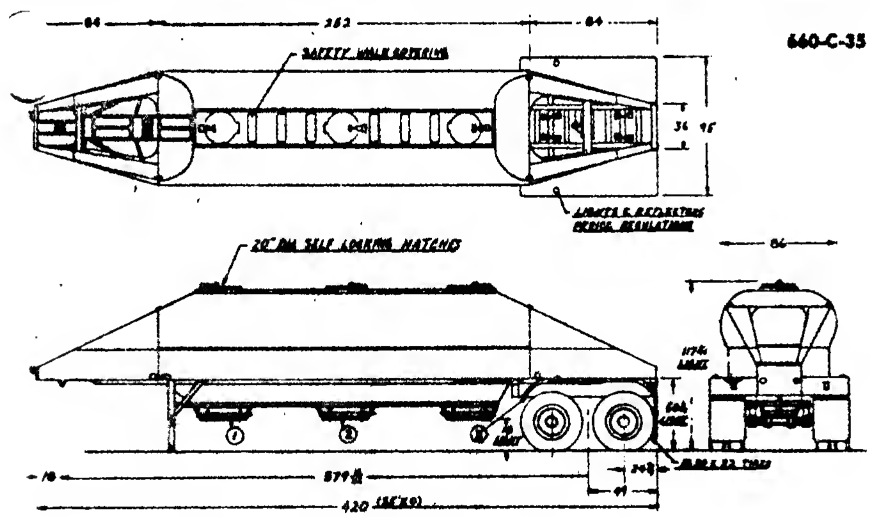
400-C-17



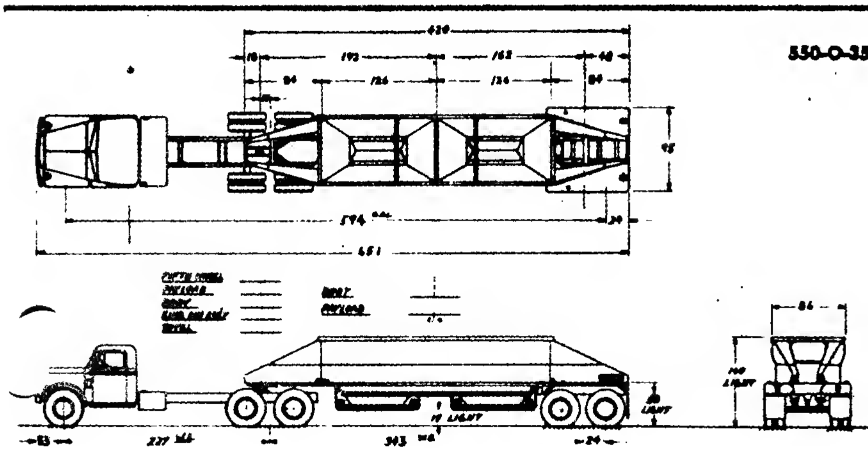
265-O-19



660-C-35



550-O-35



Above drawings are typical examples only. Actual dimensions on wheel bases vary with size and weight of tractor. Dimensions subject to change without notice.

Models 660-C-35 and 550-O-35, the latter not illustrated but similar in design and construction to Model 265-O-19, are designed for installation on dual suspension trailer underconstruction for use with dual drive tractors. They are excellent where weather and road conditions demand dual drive tractor use or to comply with special road restrictions.

Any of the models shown are readily adaptable through minor modifications for hauling varied dry bulk products, such as chemicals, fertilizers, grain, animal feeds, and many others.

Gar Wood research continually is striving through better design and construction to develop the lightest possible bodies for the greatest possible payload. Call on Gar Wood for bodies designed to best meet your job needs.

Body Specifications

Model	400-C-17	265-O-19	660-C-35	550-O-35
Approx. weight in pounds, complete train assembly, exclusive of fenders and flaps.	3,940	5,610	4,650	6,685
Body capacity, cu. ft.	400 each body	265 each body	660	550
Approx. overall body length in feet.	17 each body	19 each body	35	35

All-welded, hi-tensile steel construction on all models. Walkways and hatches only on Models 400-C-17 and 660-C-35 are of aluminum.

Vented hatch covers with self-closing latches, butterfly gates with interchangeable water-tight cover plates and dumping boot on Models 400-C-17 and 660-C-35.

Air-operated, double-acting clamshell gates on Models 265-O-19 and 550-O-35. Spreader chains furnished for adjusting opening for positive positioning. Weights shown above for the 265-O-19 and 550-O-35 are based on the 40x60 and 40x64 gate size respectively.

Exhibit 2: Dimensions and Weights of Several Gar Wood Hopper Trailers.

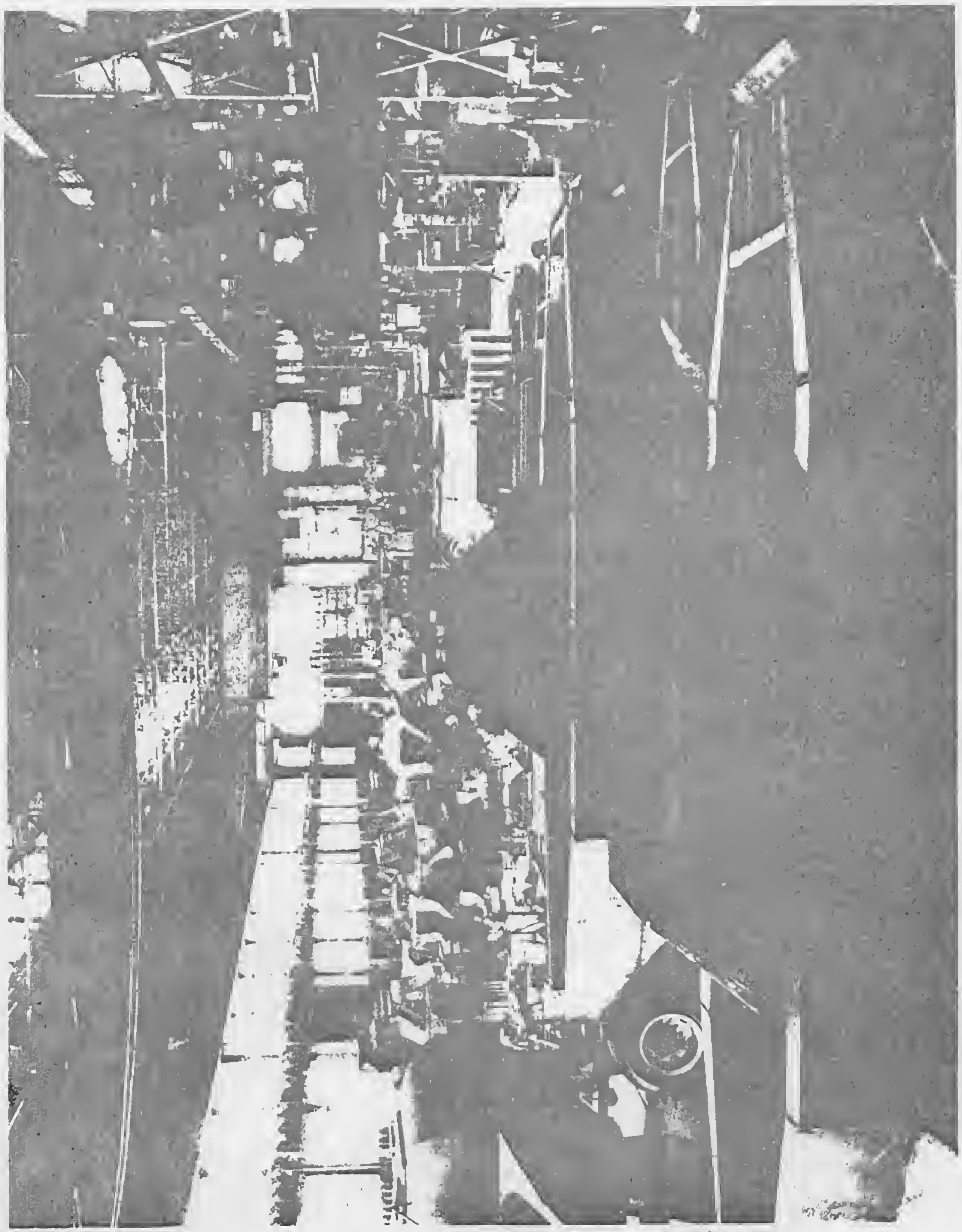


Exhibit 3: Gar Wood's Richmond Shop. Inverted Hopper Trailer Bodies in Foreground.

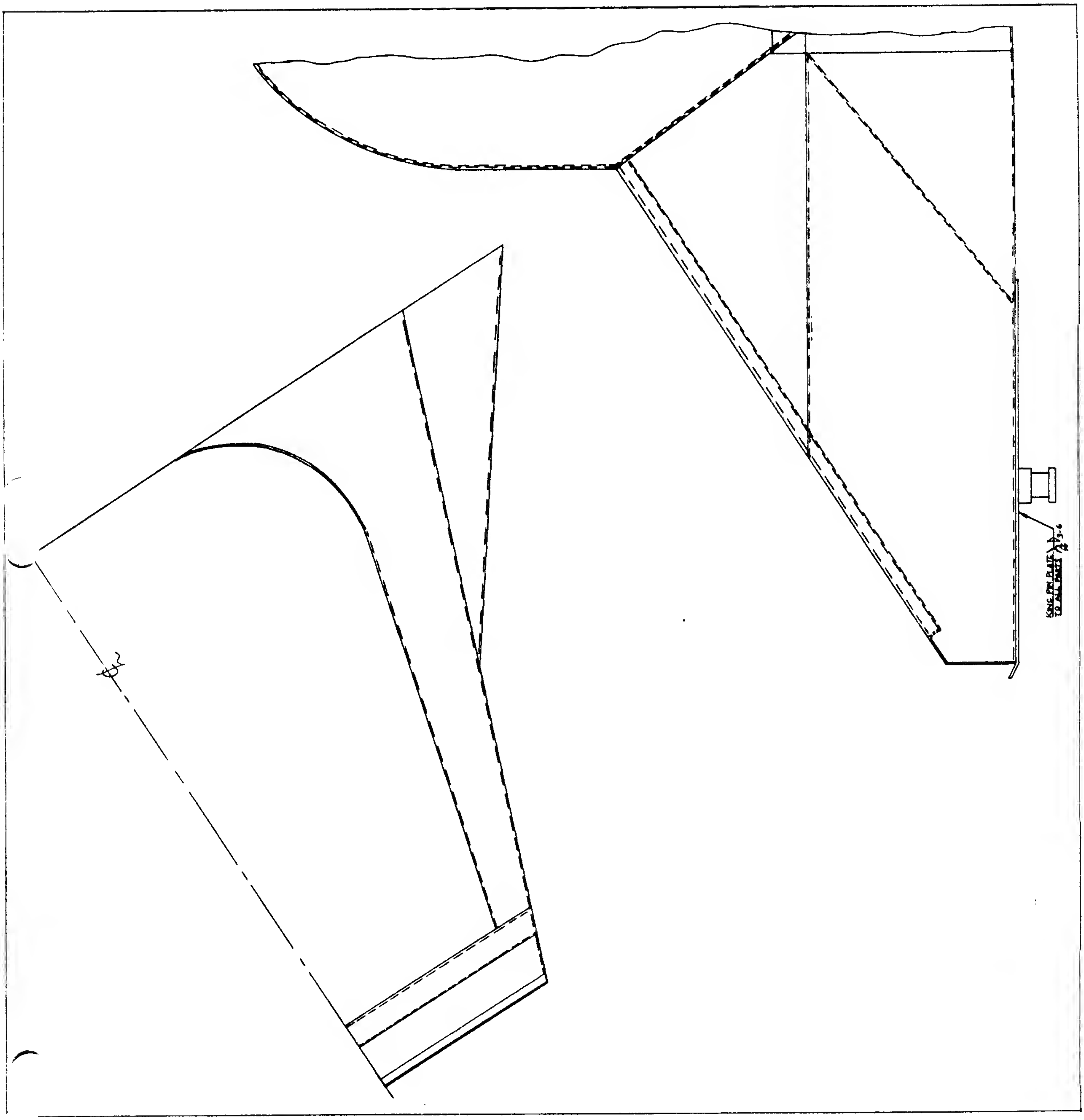
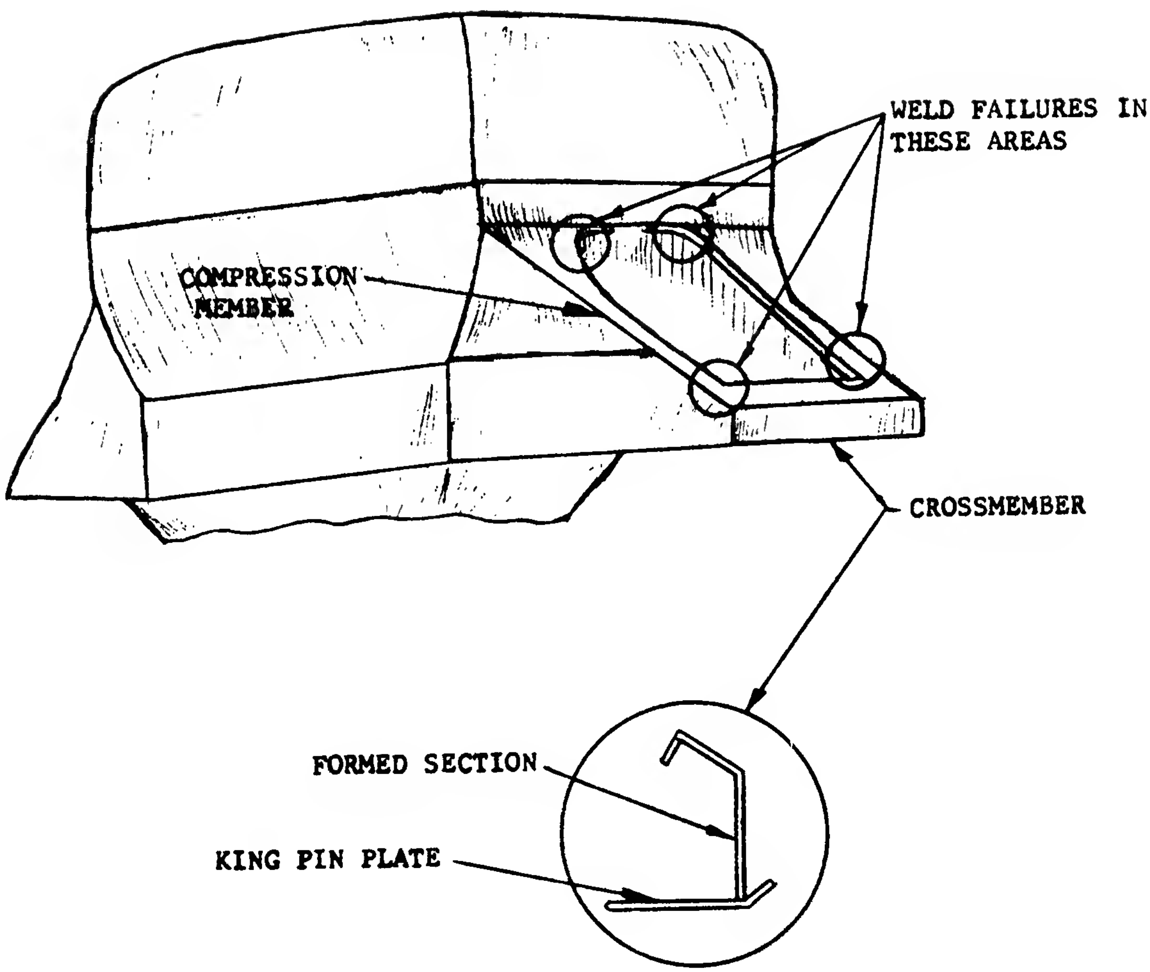
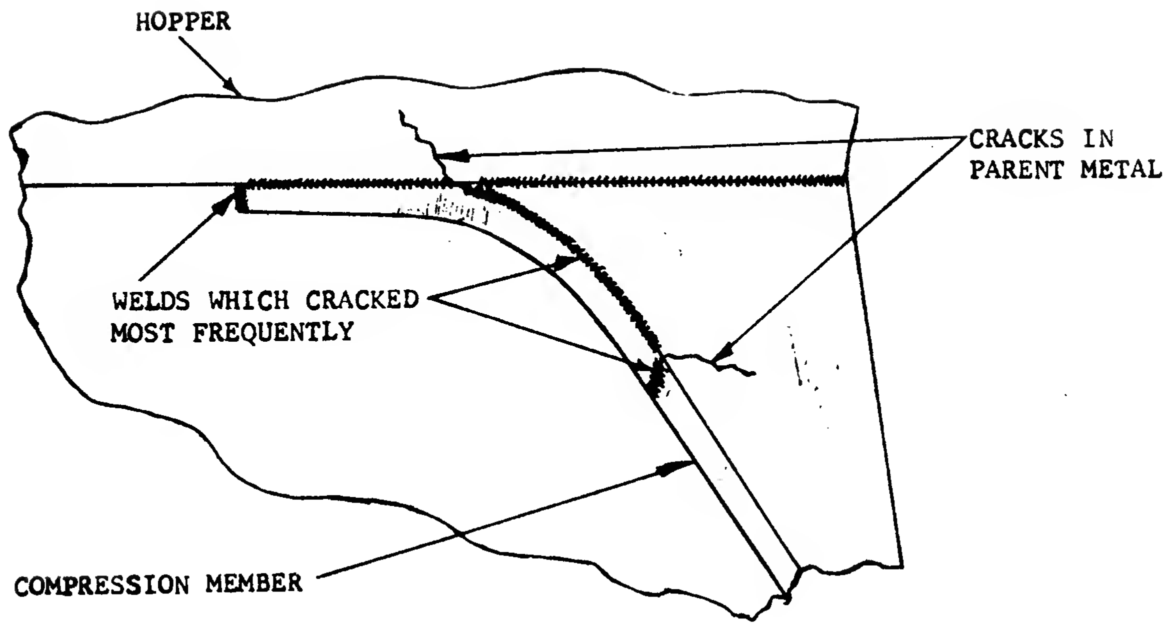
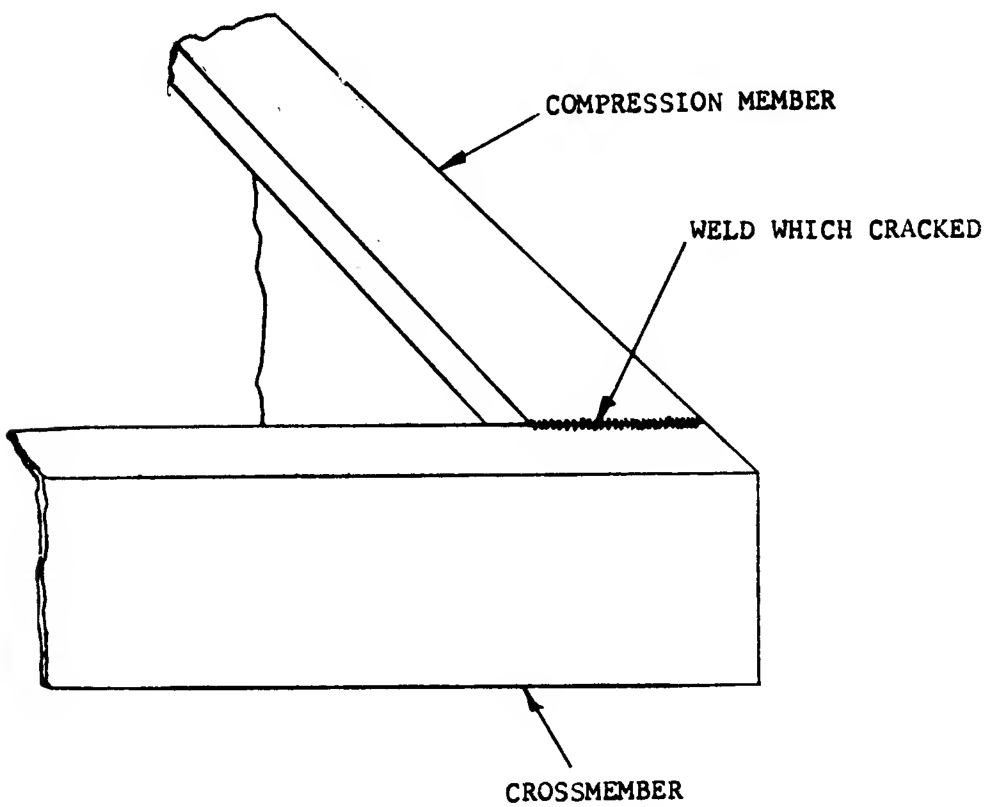


Exhibit 4: Layout of Original 1953 Body End Design.



<u>Exhibit 5</u>: Sketch of Original 1953 Model 400-C-17 Hopper Body Showing Crack Areas.


HOPPER
CRACKS IN
PARENT METAL
WELDS WHICH CRACKED
MOST FREQUENTLY
COMPRESSION MEMBER


COMPRESSION MEMBER
WELD WHICH CRACKED
CROSSMEMBER

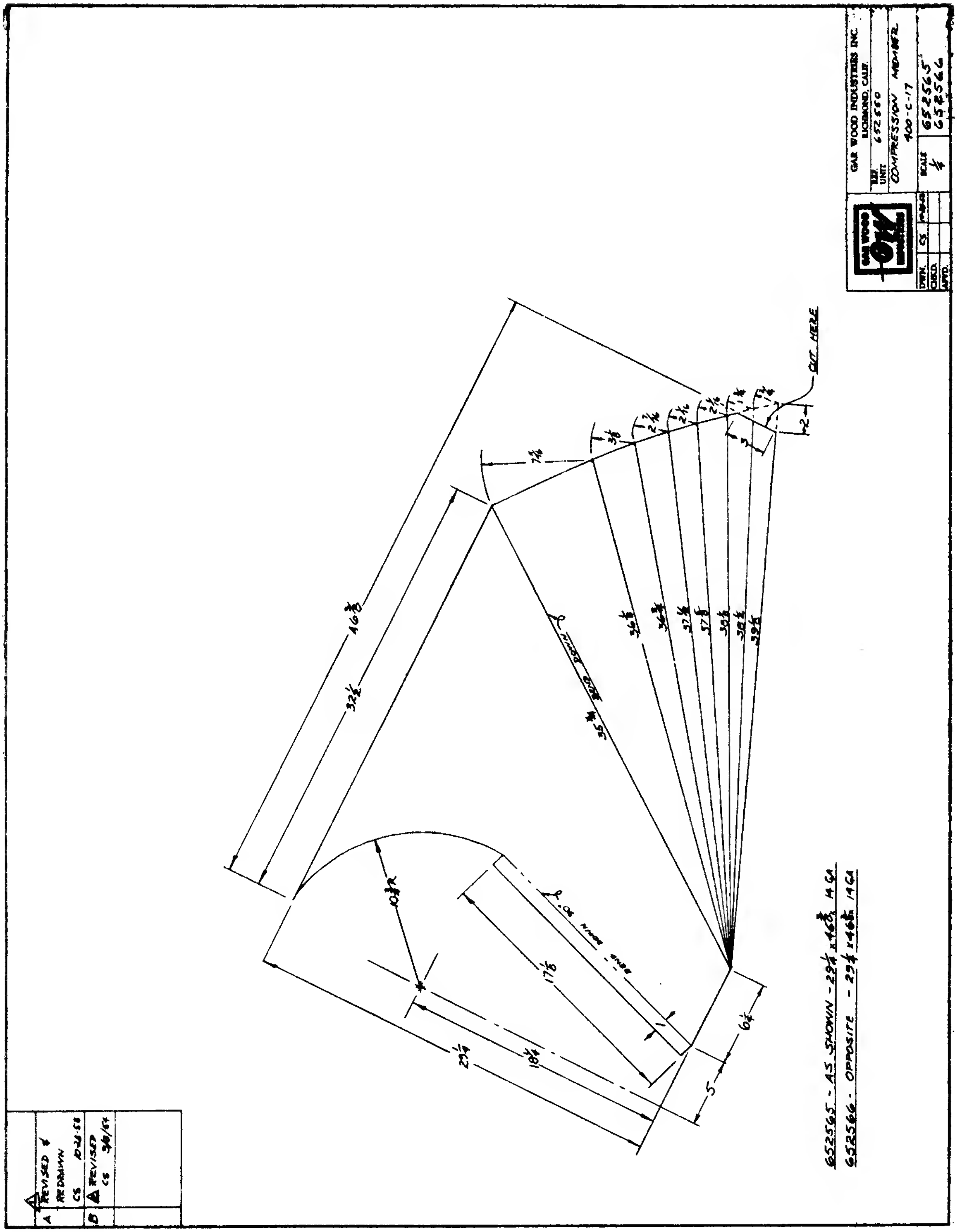


Exhibit 6: Original 1953 Compression Member.

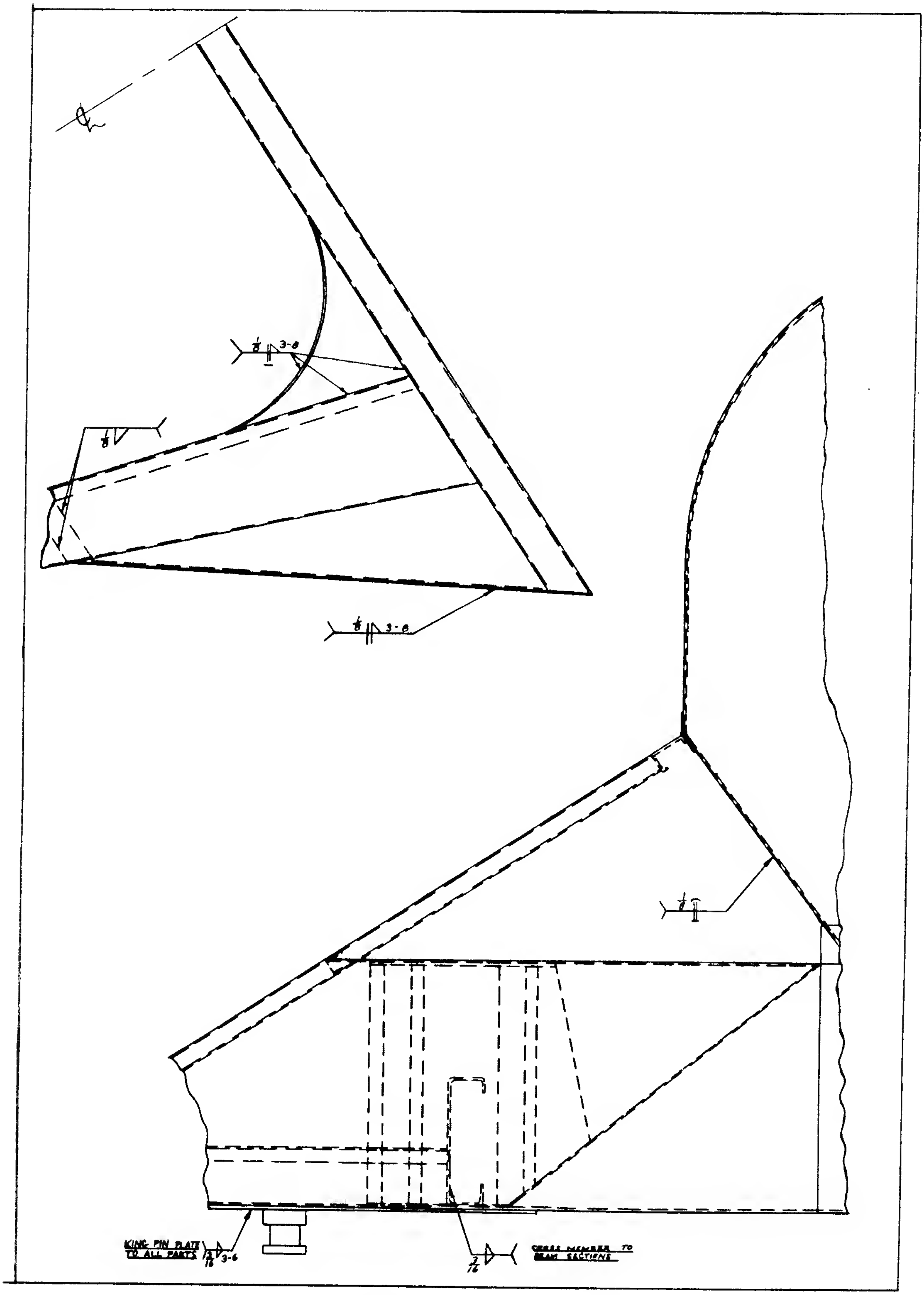


Exhibit 7: Layout of Joint Between Compression Member and Crosswise Channel on Hopper Wall After Redesign of August, 1954.

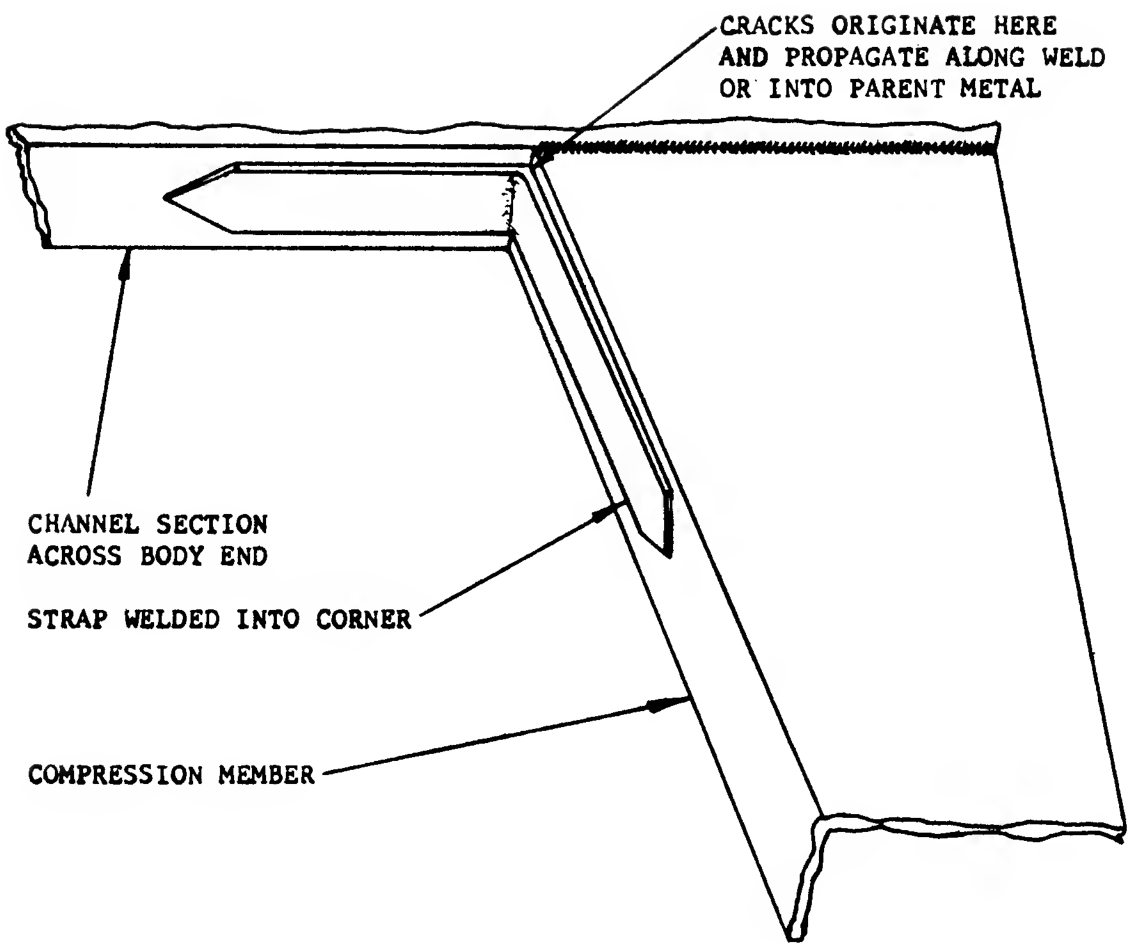


Exhibit 8: Sketch of Body End with Strap in Corner But No Gusset.

The frameless hopper trailers were designed, and are manufactured, at Richmond, although most of Gar Wood's product design and development activities are carried out at the company headquarters in Wayne, Michigan. Bottom dump hopper bodies are built in more than 20 different models. Two are shown in Exhibit 1. Bodies are of various lengths and capacities and may be open-topped or closed The 400 in the model number of the trailers in the top picture is the nominal capacity in cubic feet, the C means the trailer is of the closed type (an O in the model number indicates an open body) and the 17 is the approximate overall length in feet. The Gar Wood bodies are mounted on purchased undercarriages to form semi-trailers or full trailers. California state law sets a maximum gross vehicle weight (GVW) of 76,800 lbs. for a train in which the distance between the frontmost axle and the rearmost axle is at least 56 feet. A train is a tractor followed by a semi-trailer and a full trailer. All three are included in the GVW. Trailers up to 21 feet in length are usually handled in train, those 28 feet long and over, singly. Twenty-six footers may go either way. Hopper trailers are used for hauling loose bulk materials such as sand, gravel, clay,and grain. The load on a trailer body depends on what it is hauling. High density materials such as clay would preferentially be carried in short trailers. Dimensions and weights of several trailers are shown in Exhibit 2. The largest model Gar Wood has built was a 1350-O-42.

The Richmond Division of Gar Wood is one of several in the company, all of which manufacture products which may be broadly classified as automotive. Products manufactured at Richmond, in addition to bottom dump hopper bodies, include end dump bodies, garbage truck bodies and various types of hoists and winches for trucks.

When Mr. Hirtle joined Gar Wood in 1952 as Chief Engineer he had been in the truck equipment business for twenty years. He was graduated from the University of Washington in 1930 with a bachelor's degree in Civil Engineering. The following two years he spent there as an instructor in the general engineering program. He is a registered Mechanical Professional Engineer in California, and a registered Civil Engineer in Washington.

The frameless trailer designed in 1953 replaced an earlier style of hopper trailer with a separate truss frame which had been designed by Mr. Hirtle's predecessor. During 1952-1953, demand for bottom dump trailers on the West Coast was increasing as truckers discovered that they could often be used to haul bulk materials more economically than the end-dump trailers used previously.

GAR WOOD INDUSTRIES INC. (B)

Failures at Welded Joints in a Hopper Trailer

E. G. Hirtle, Chief Engineer at the Richmond (California) Division of Gar Wood Industries Inc., had decided near the end of 1955 to allow flexing at a corner joint in Gar Wood's line of frameless hopper trailers in an attempt to eliminate weld failures. Cracks were found at the corner between the crosswise channel welded to the hopper wall and the compression member after a number of trailers had been built without gussets at the corner. The cracks then propagated from the point of inception, where all the flexing was now concentrated, along the welds or into the parent metal.

During an informal discussion in the early months of 1956 involving several of the engineering staff who were acquainted with the corner bracket problems, a new gusset idea was born. Mr. Hirtle said that many good ideas originate in such seemingly aimless sessions. This idea was the humped gusset shown in the drawing of Exhibit 1 and the photograph of Exhibit 2.

In the humped gusset design the strap in the corner is retained in modified form. In the gusset-less corner, the strap was one piece bent at an acute angle to fit the corner. In the new design the leg strap is continued along the channel section behind the compression member to give added weld length. As originally set down in April, 1956, the "base" was 1-3/4" x 16" x 1/4" mild steel, and the leg was 1-1/2" x 8" x 1/4" mild steel. These dimensions were changed to those shown and noted on the drawing of Exhibit 1 in January, 1959. At that time the width of the base was increased to 2-1/4 inches to match that of the crosswise channel section to which the base was welded. This gave a better weld.

The gusset itself is humped -- bent up 41° -- to allow flexing. The general idea of permitting flexibility was not abandoned, but the gusset is now intended to control this flexing in such a manner that cracks will no longer occur. Instead of all flexing being concentrated at the corner point, the humped gusset spreads the stresses over a length of several inches on either side of the corner. Since the gusset can flatten slightly or bend further upwards as loads are applied, the welds in the area are not overloaded each time the trailer goes over a bump. The 41° bend angle was chosen as convenient

The drawing of Exhibit 1 shows a change in the gusset from 8 gage (.164) material to 3/16 inch stock in April, 1957. This was not a functional change. At that time Gar Wood was no longer stocking 8 gage steel; this was the only reason for the change.

The humped gusset has proven satisfactory in service, effectively eliminating failures at the corners of the upper ends of the compression members. In fact, Gar Wood has adapted the idea to many other gussets and brackets, both on the hopper trailers and on other products.

Design Changes at the Joint Between the Compression Member and the Crossmember

In the original design as set down in 1953, the two compression members in each body end were joined by a deep crossmember across their ends as shown in Exhibits 1, 4, and 5 of Part (A) of the case. The crossmember was 10 gage (.134) low alloy steel and was welded between the ends of the two compression members, which were of 12 gage (.105) stock. The front of the king pin mount or fifth wheel plate was welded to this crossmember; in the rear of the trailers a similar structure attached to the undercarriage. The welds between the crossmember and the compression member failed as shown previously in Exhibit 4 of Part (A). Cracks usually propagated from the welds on into the compression member rather than into the crossmember.

When flat plate gussets were added across the corner between the two members, cracks formed at the ends of the gussets where they met the compression members as shown in the sketch of Exhibit 3 of Part (B).

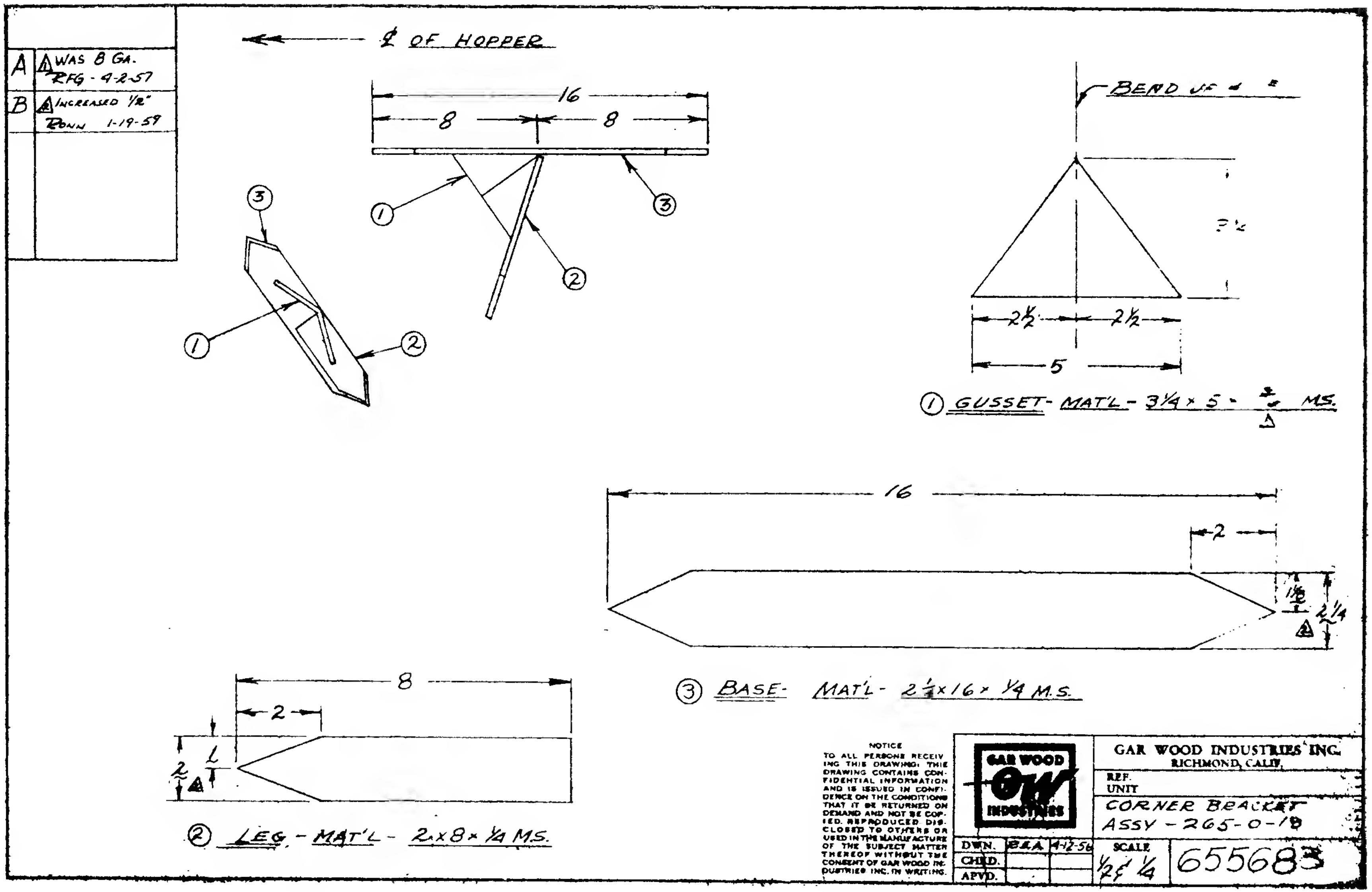
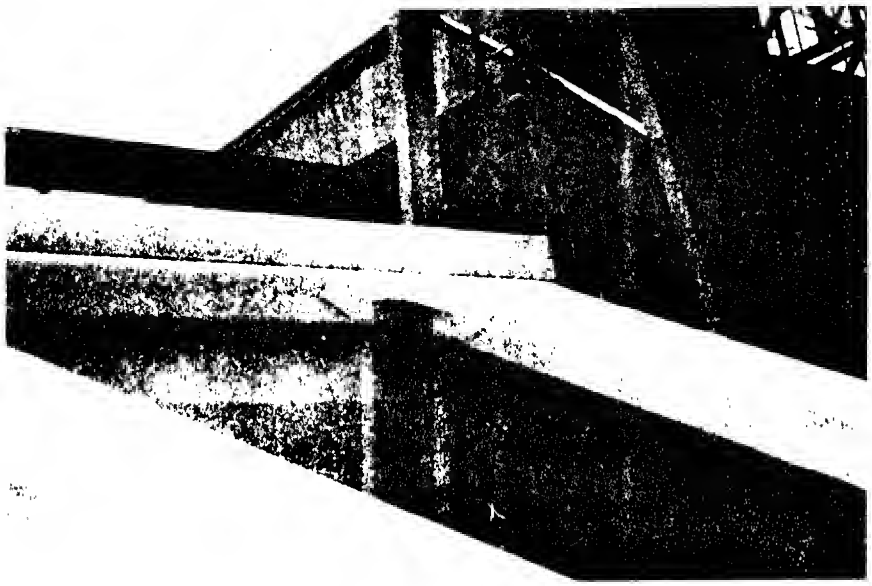


Exhibit 1: Humped Gusset for Corner Between Compression Member and Crosswise Channel on Hopper Wall.



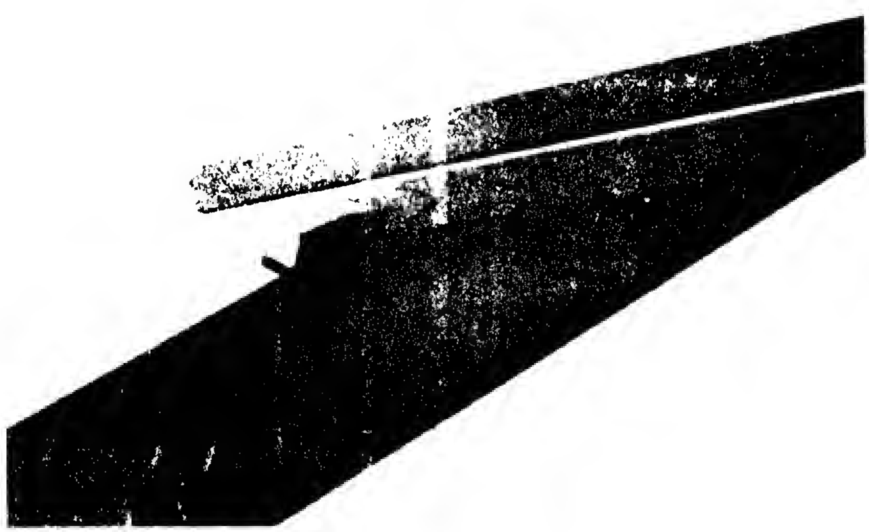


Exhibit 2: Humped Gusset at the Compression Member to Hopper Wall Joint.

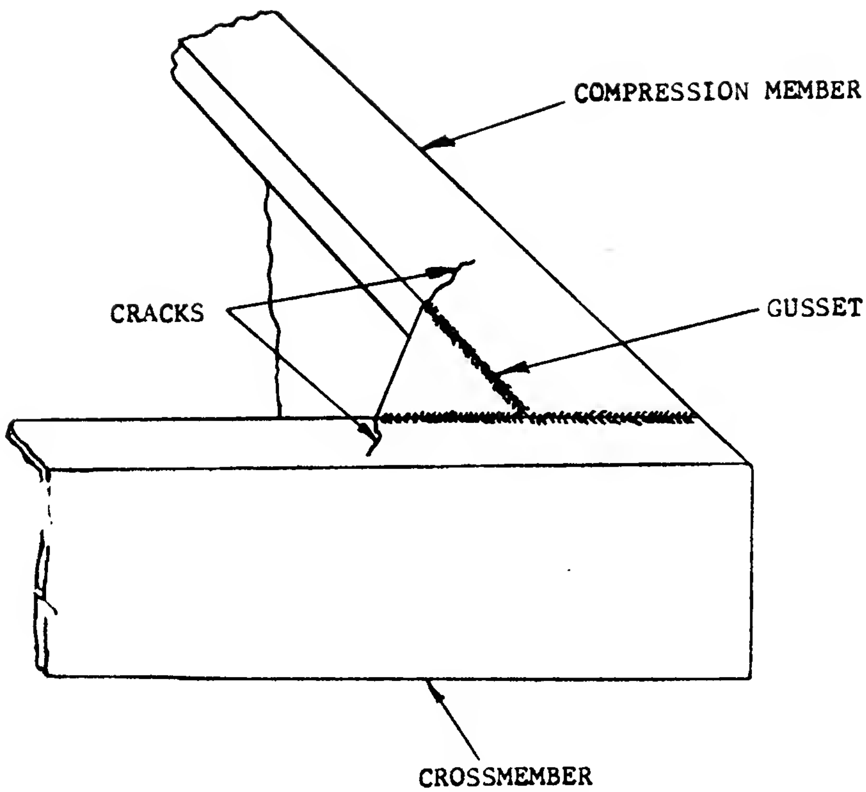


Exhibit 3: Sketch Showing Cracks at Compression Member to Crossmember Joint Following the Addition of a Gusset.

GAR WOOD INDUSTRIES, INC. (C)

Failures at Welded Joints in a Hopper Trailer

After Gar Wood's frameless hopper trailer had gone into service in 1953 with a crossmember welded between the lower ends of the two compression members, cracks developed in the welds.

E.G.Hirtle, Chief Engineer at Gar Wood's Richmond (California) Division, recalled that adding gussets across the corner during the early months of production in 1953 did not help much.

In September, 1953, Bill Batson*, Assistant to the Vice President of Engineering at Gar Wood's Wayne, Michigan, headquarters, was visiting Richmond on another matter. Mr. Batson acted as a troubleshooter and consultant to the various divisions of the company on engineering matters. Mr. Hirtle knew him as a man with an excellent theoretical background in the engineering disciplines who had an uncommon ability to put his knowledge to practical use. Since Mr. Batson was in Richmond, Mr. Hirtle asked him for ideas on the crossmember problem. Mr. Batson then suggested that a bolted connection be used between the crossmember and the bottom end of each compression member. He said that a single bolt at the shear center of the compression member should be used. The idea was that this would eliminate torsion on the lower end of the compression member; the member would then be in pure bending and would not be twisted apart, as was now suspected had been happening.

Mr. Batson's suggestion was implemented. Mr. Hirtle explained that, since the compression member was, in section, essentially a channel of varying height, it was necessary to assume it to be a beam of constant cross-section when computing the location of the shear center. The section size assumed was one nearer that of the lower end of the member, since it was at this end that the cracks were developing and thus here that it was desirable to eliminate twisting.

When the shear center had been located, an angle bracket was designed that could be welded to the lower end of the compression member to locate a bolt at this point. Then the crossmember itself was redesigned; it was made shallower so that its depth was only partially that of the ends of the compression members and so that it would fit beneath the angle brackets.

*Fictionalized name.

At the same time it was made stronger by increasing the material thickness from 10 gage (.134) to 1/4 inch. This crossmember is a piece of channel. It becomes a box section when the king pin mount or 5th wheel is welded to its open (underneath) side. The angle bracket is shown in the drawing of Exhibit 1 and the assembled connection in the drawing of Exhibit 2 and the photographs of Exhibit 3.

A 7/8 inch bolt is used to join the crossmember to the bracket on each compression member and the two facing surfaces are separated by a washer to ensure that the load is actually concentrated at the shear center. Mr. Hirtle explained that while this design was a definite change away from the attempts at massive strength and rigidity in the original, the aim of the bolted connection is to eliminate twisting forces and not to make the joint flexible. However, the flexible connection afforded by the isolated bolts was no doubt an added advantage. Mr. Hirtle stated that a bolted connection between the crossmember and the compression members would almost certainly have resulted in continued problems -- cracking of the metal around the bolts for example -- if the bolts had not been placed at the shear center of the compression member.

Although there have been a number of changes to the angle bracket and the crossmembers since they were first designed, the only change made as a result of further failures around the bolted connection came in 1959 when the fish tail doubler plate shown in the drawing of Exhibit 4 was added. Previously, the angle bracket of 1/4 inch plate, had been welded directly to the 12 gage (.105) compression members. However, the bracket occasionally tore loose in service. The fish tail doubler plate was added (it can be seen in hidden lines in Exhibit 2) to stiffen the compression member locally and give more area to the welded joint between the angle bracket and the compression member. The four one inch holes in the doubler plate are for plug welds to help hold the plate to the compression member.

Since 1959, there have been no further functional changes to this connection and the design has proven satisfactory.

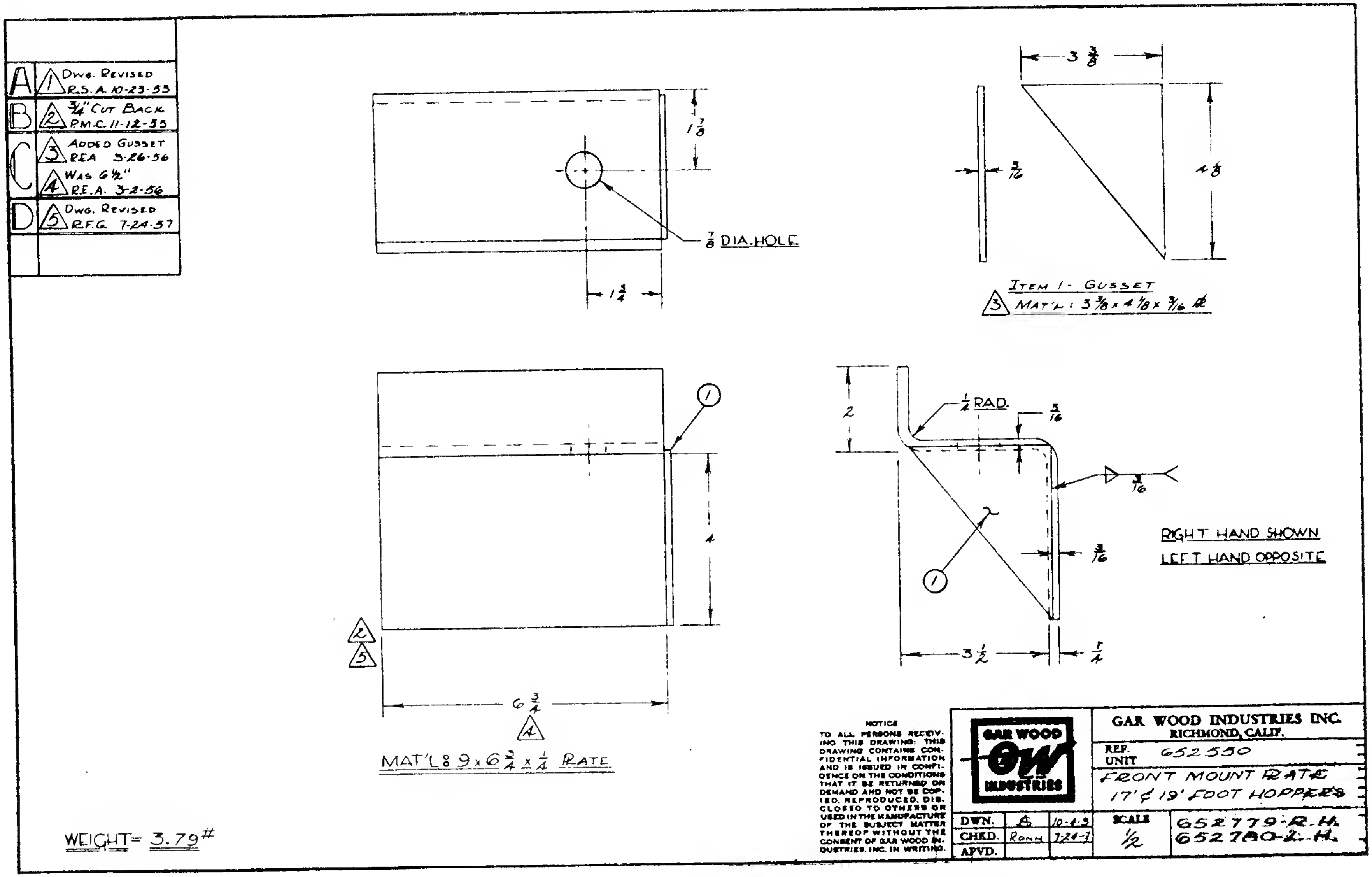


Exhibit 1: Angle Bracket to Locate Bolt at Shear Center of Compression Member.

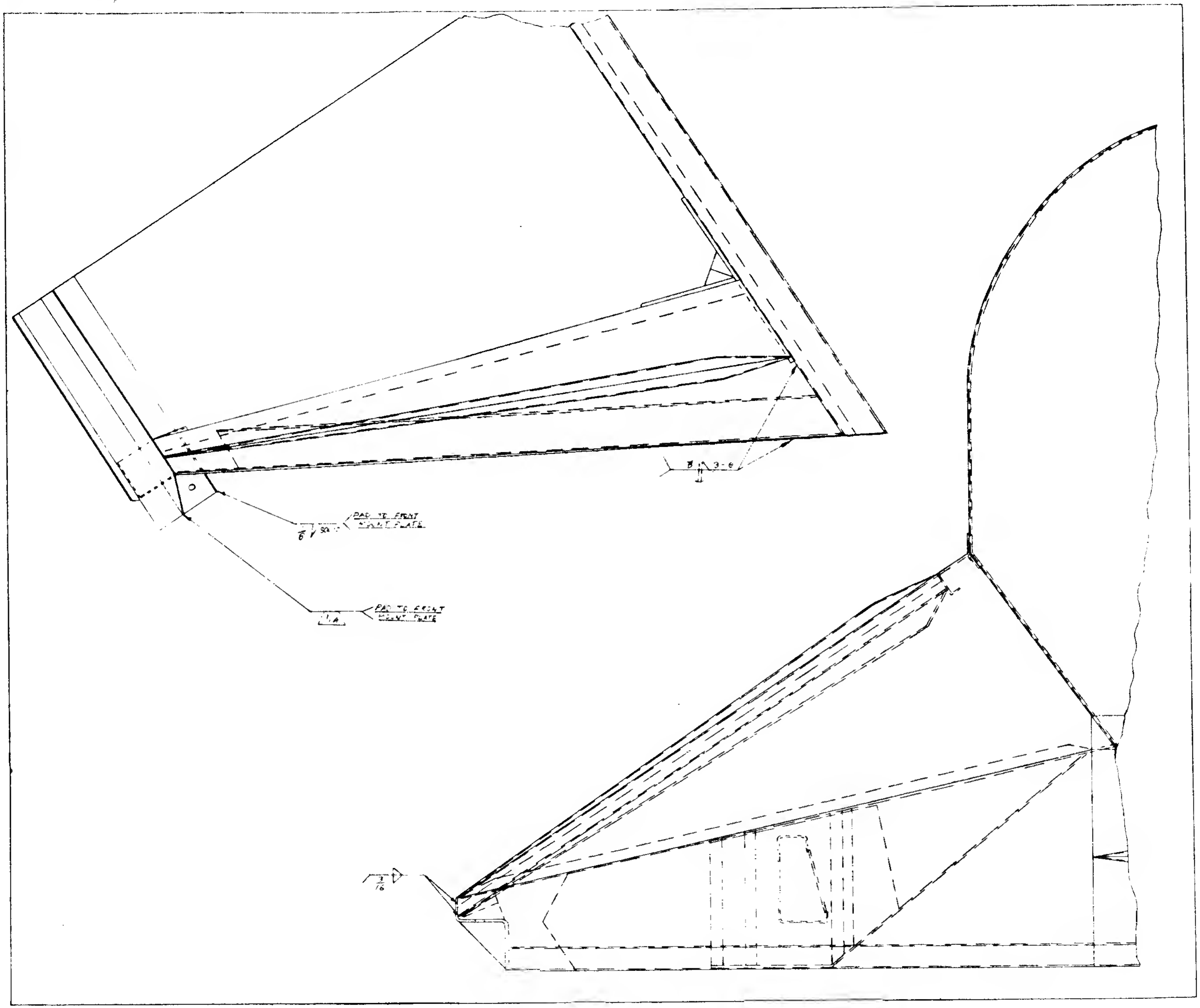
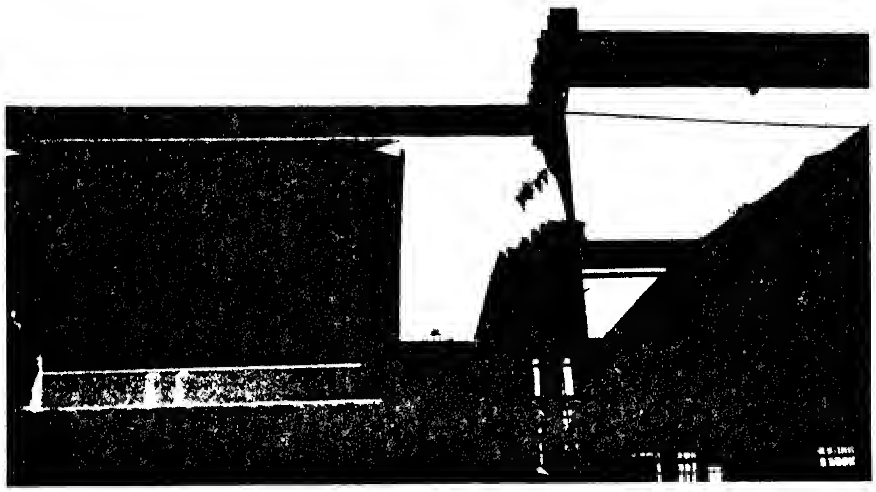


Exhibit 2: Layout of the Final (and Current) Body End Design Including Shear Center Bracket (late 1953), Humped Gusset (early 1956) and Fish Tail Doubler Plate (1959).



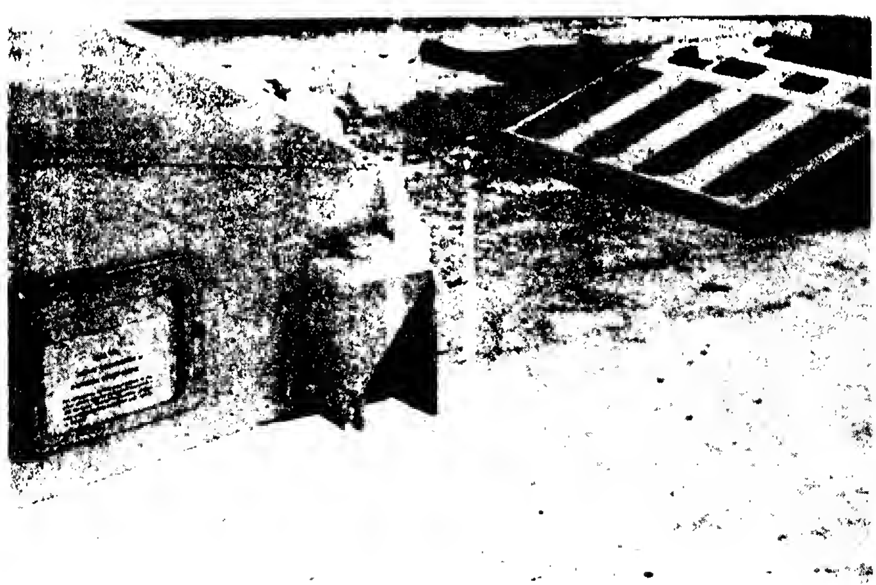


Exhibit 3: Shear Center Bracket at Bolted Connection Between Compression member and Crossmember.

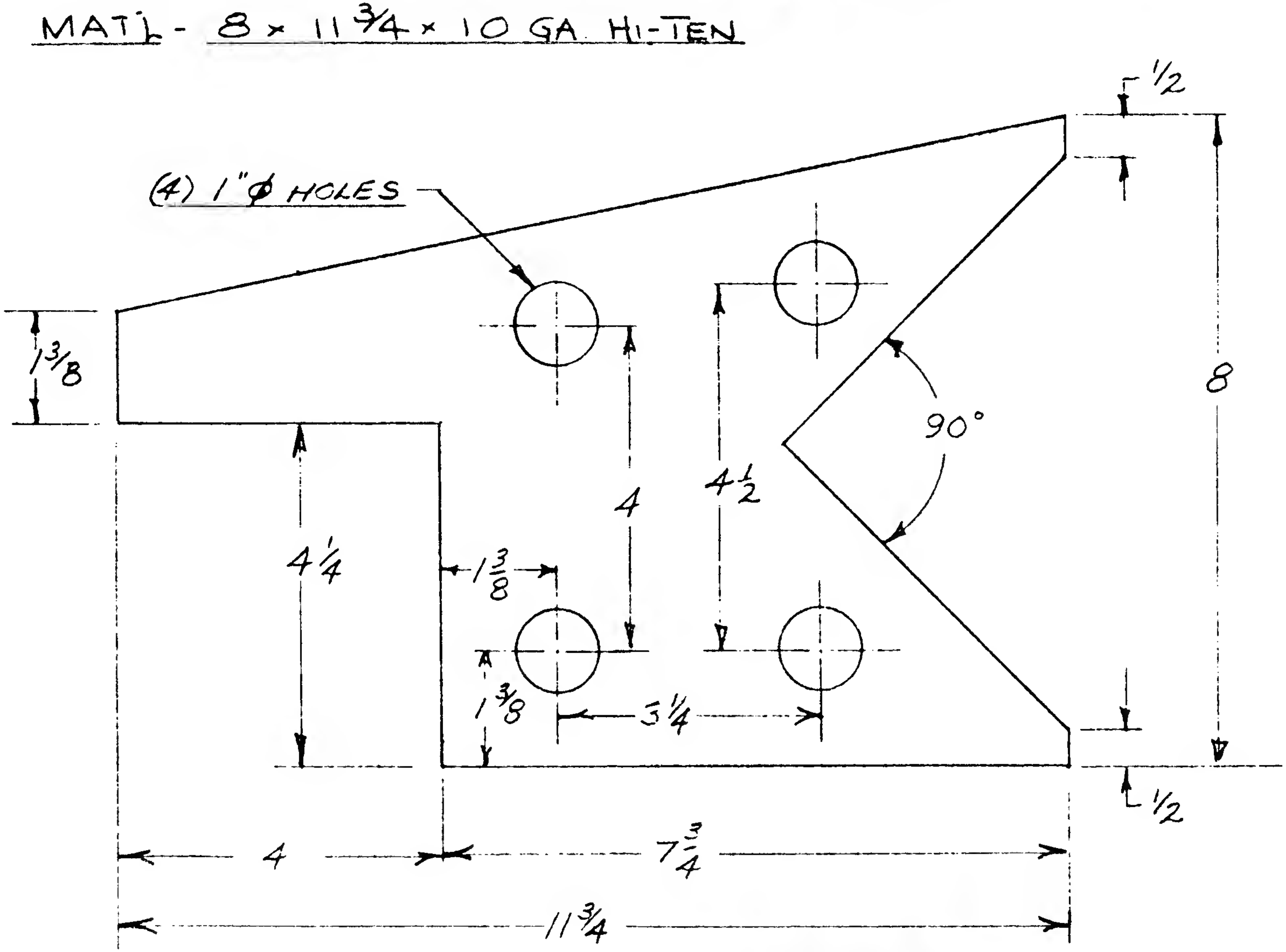


Exhibit 4: Fish Tail Doubler Plate for Reinforcing the Joint Between the Shear Center Bracket and the Compression Member. Added in 1959.

REDRAWN - 3-7-62

ALLOWABLE VARIATION ON FRACTIONAL FINISHED DIMENSIONS IS PLUS OR MINUS .010" UNLESS OTHERWISE SPECIFIED.

GAR WOOD INDUSTRIES INC.
RICHMOND, CALIF.

DWN.	RFH	3-7-62	REF. UNIT	655471/2
CHKD.			FISH TAIL DOUBLER PLATE - 275-0-19	
APVD.			SCALE 1/2	656811

ECL 42-C
Exhibit 4